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OIL ABSORBENCY AND PLIABILITY PROPERTIES OF N95 RESPIRATOR TEXTILE SUBSTRATES IMPREGNATED WITH ALOE VERA AND SODIUM CHLORIDE

KESKIN Reyhan

Pamukkale University, Engineering Faculty, Dept. of Textile Engineering, Kinikli, 20070, Denizli, TURKIYE,
E-mail: reyhank@pau.edu.tr

Corresponding author: Keskin, Reyhan, E-mail: reyhank@pau.edu.tr

Abstract: *In this study, it was aimed to assess oil absorbency properties besides pliability of polypropylene substrate materials used to produce respirator N95 masks with samples impregnated in Aloe Vera and NaCl salt solutions. Salt solutions of samples were 1, 5 and 10 weight %. Aloe Vera content was kept constant as 33 wt % of mixtures in which sample was impregnated. Aloe Vera impregnated samples were better to absorb glycerol compared to control samples in sinking tests. Polypropylene samples impregnated into Aloe Vera added salt solutions outperformed oil absorbency of Aloe Vera impregnated samples with shorter absorption time intervals during sinking. Wicking tests with droplets of glycerol and the areas of droplet capillary absorption showed that control samples had better oil wicking properties, but still all impregnated samples showed degrees of capillary intake of glycerol droplet during wicking tests. Masks need to ensure a stable breathing area and also a certain amount of flexibility. Bending length test results proved Aloe Vera impregnated respirator substrates had shorter bending length, as a result better pliability, compared to control samples.*

In conclusion, the property of absorbing glycerol is a sign of hydrophobicity which is good for preventing human body fluids from sticking on the fibrous materials such as wound dressing or facemasks touching wounds that are on their healing process. The hydrophobic characteristics of the N95 mask fabric might be a good candidate for patients that have to wear masks over some wounded body part as hydrophobic wound dressings are good candidates to heal wounds with thick exudates which are coagulation of proteins in the wounds and have hydrophobic characteristics. Increase of pliability for N95 respirator substrates might give freedom to give shape to the mask and increase face fitness of the respirator.

Key words: *N95 respirators, Aloe Vera, sodium chloride, oil absorbency, pliability.*

1. INTRODUCTION

Respirators and surgical face masks have been a part of our lives since the corona virus (Covid 19) pandemic. Surgical masks are loose fitting personal protective equipment (PPE) that cover the nose and mouth of the wearer while respirators such as N95, N99, and N100 are tight fitting masks with a facial seal [1]. Personal protective equipment (PPE) is essential for healthcare personnel to protect them from viral respiratory diseases such as influenza. Much of the influenza transmission study is concentrated on “the droplet spray-aerosol transmission” rather than contact transmission. Aerosol transmission can take place both in short distances as well as longer distances due to air currents [2]. Surgical masks are not designed to protect the wearer from inhaling airborne bacteria or virus particles, surgical masks are PPE designed to be worn by healthcare professionals, to catch bacteria in liquid droplets and aerosols that might be spread from the mouth and nose of the wearer (healthcare personnel) in order to protect the patient from healthcare personnel potential transmission risk due to their coughs and sneezes. Respirators are designed to provide protection to the wearer due to inhalation of airborne particles that might be possible danger risk to the inhaling person [1].

Hewawaduge et al (2021) studied antiviral efficiency of copper impregnated three-layer mask against SARS-CoV2 virus. The impregnated and coated outer layer contained 4.4 weight % of CuS (copper sulphite) while the impregnated middle nylon layer had 17.6 weight percent CuS [3]. Jung et al (2021) studied copper coated polypropylene (PP) filter face masks and concluded copper-coated antiviral PP filters could be key solutions for personal protective equipment but also for air-conditioning materials [4]. Although nano silver and nano graphene particle coated facemasks protect against Covid-19 virus, these nano particle coated masks pose health risks to the wearer such as DNA damage induction, in-vitro repeated dose toxicity dermal exposure and in-vitro skin sensitization [5]. Due to posed hazards of nano particle coatings on facemasks, natural coating materials are studied as possible candidates for facemask impregnation materials [6, 7]. Schorderet Weber et al (2022) studied the potential of coronavirus antiviral efficacy of salt coated face mask fabrics and concluded that salt coatings on facemasks disrupted the virus cells and the viral replication decreased, however pre-incubating the virus in hypertonic salt solutions did not reduce the infectivity of the Corona virus. Researchers used 0.9 weight (wt) %, 3.5 wt % and 35 wt % saline solutions for spraying and dip-coating face masks. The deposited salt was calculated by weighing the sample before coating and after drying at room temperature overnight. The findings of the study show that salt forms a protective antiviral barrier both on surgical masks and on household textiles to be used for home-made masks such as washable cloth masks [8]. Pepito et al (2022) studied the antimicrobial efficacy of OSS (Omani sea salt) saline loaded middle layer and whole mask of surgical mask materials. Fabrics were soaked in saline solutions for 24 hours. According to the study, 30 wt % salt loading did not show any antimicrobial activity, however 10 % sodium hydrogen carbonate ($NaHCO_3$) addition to OSS solutions showed antimicrobial efficacy both in dried samples and soaked samples [9].

As Aloe Vera contains biocomponents having potential action on microorganisms and having been used for hundreds of years for its healing potential, Z.Edis et al (2022) studied the antimicrobial efficacy of Aloe Vera on sutures, bandages and face masks. The researchers concluded that their Aloe Vera and iodine including compounds are effective in treating infectious diseases on sutures, bandages, unanimated surfaces and face masks [7]. Gorade et al (2021) investigated wicking property of microcrystalline cellulose (MCC) applied polypropylene (PP) fabric with the vertical strip wicking test at time intervals of 10, 30, and 60 seconds. The water wicking height increased at MCC applied PP fabric compared to the zero cm water wicking height at the untreated control PP sample [10]. Castillo et al (2022) increased the polypropylene fabric water absorption capacity to 5.8 g/cm2 hydrophilicity by surface modification using particles of a mineral, a zeolitized vitreous breccia [11]. N95 respirators have a ventilator fan and four layers: outer layer polypropylene non-woven layer, filter polypropylene layer, support modacrylic layer and mask inner polypropylene layer [12]. Spunbonded and meltblown nonwoven layers are laid in several combinations to ensure N95 respirator layers are obtained.

Many researchers studied filtration of respirator media including surgical masks and N95 masks [2], however, improvement ways of PPE masks in terms of fitting to the face, user seal effectiveness and several physical properties related to pliability and flexibility of mask materials are still emerging issues for research of surgical masks. In this study, it was the aim to assess oil absorbency properties besides pliability of respirator mask materials according to bending strength tests for Aloe Vera and NaCl salt impregnated respirator N95 masks.

2. EXPERIMENTAL APPROACH

2.1 Materials and Method

In this study pure sodium chloride (NaCl) from Riedel-de Haen, 100% Aloe Vera gel from CireAceptine Company, distilled water and a 250 g/m2 polypropylene spunbonded nonwoven fabric at 0.16 mm thickness from Mogul Textiles Company was used. The nonwoven substrates rolled on bobbins at 18 cm width were used as received. Aloe Vera gel was used as received from the plastic bottles sold in the market.

Preparation of Impregnation Baths

At trials, the nonwoven substrate did not take in any salt solutions. Aloe Vera added salt solutions were successful for impregnating polypropylene substrates. Samples codes and their mixture contents are shown in Table 1. Salt solutions of samples were 1, 5 and 10 weight %. Aloe Vera content was kept constant as 33 wt % of mixtures in which sample was impregnated.

NaCl solutions were mixed at 80 rpm at room temperature until stock solutions were obtained. NaCl stock solutions were prepared using distilled water at 10 wt%, 20 wt% and 25 wt%. Stock solutions were diluted to prepare impregnation baths. Aloe Vera gel was added into NaCl diluted solutions to obtain "salt and Aloe Vera" having solutions. To obtain 'only Aloe Vera' having samples Aloe Vera gel was diluted in distilled water and stirred at 80 rpm with the magnetic stirrer.

Impregnating Nonwoven Substrates

Nonwoven substrates were impregnated in the mixture baths for half an hour using Kucuker Textile brand laboratory type pad batch machine. Samples were padded at around 95-100 % liquor uptake during the impregnation period. For Aloe Vera containing samples, Aloe Vera gel weight was added into sodium chloride solutions to obtain 33 wt % of gel in mixtures. Impregnated samples were dried at 130 C^o in laboratory type oven for four hours.

Table 1. Samples and codes

Sample code	Salt solution wt %	Aloe Vera gel wt %	Salt (g) in mixture	Aloe Vera gel (g) in mixture	Deionized water (g) in mixture
N_control	_	_	_	_	100
N_AV	_	33 wt %	_	33	67
N_s1_AV	1 wt %	33 wt %	1	33	66
N_s5_AV	5 wt %	33 wt %	5	33	62
N_s10_AV	10 wt %	33 wt %	10	33	57

Testing Methods

As polypropylene based materials showed neither any water absorption properties nor any water wicking properties, the absorption of glycerol by samples and the wicking of glycerol droplets were tested. Figure 1 shows a colored water droplet on the hydrophobic nonwoven substrate.

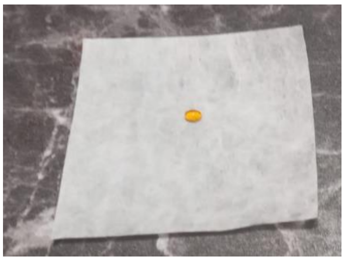

Fig. 1 *Hydrophobic polypropylene substrate (N_control) and a water droplet*

For glycerol absorption tests, sinking time test in glycerol was carried out. The sinking time indicates the affinity of the substrate to oleic fluids and proves absorption in the manner of a sponge taking fluid in its structure. Control polypropylene nonwoven samples had an approximately 24 second time for glycerol absorption, and Aloe Vera impregnated samples were better to absorb glycerol compared to control samples. Polypropylene samples impregnated into Aloe Vera added salt solutions outperformed oil absorbency of Aloe Vera impregnated samples with shorter absorption time intervals. Sinking times in glycerol show that Aloe Vera and sodium chloride impregnated samples have ability to take into hydrophobic fluids like oils and proteins. Table 2 shows sinking time of samples in glycerol.

Table 2. *Sinking time test results of samples in glycerol*

Sample code	Sinking time (sec)
N_control	24.25 ± 5.18
N_AV	2.75 ± 0.35
N_s1_AV	1.84 ± 0.61
N_s5_AV	1.21 ± 0.29
N_s10_AV	0.88 ± 0.11

Wicking tests were conducted with droplets of glycerol. During wicking tests with glycerol droplets, Aloe Vera and NaCl solutions impregnated samples (N_AV) and NaCl solution and Aloe Vera impregnated samples (N_s1_AV, N_s5_AV and N_s10_AV) showed smaller absorbed areas and lower capillary intake of hydrophobic fluid than pure polypropylene samples (N_control). Pure samples had better oil wicking properties, but still all impregnated samples showed degrees of capillary intake of glycerol droplet during wicking tests. The droplet absorbed area is slightly decreased with salt and Aloe Vera loading, which might be a chance to tune mask material hydrophobicity level according to usage areas and user needs. The sample areas of the absorbed glycerol droplet are listed in Table 3.

Table 3. *Absorbed area for "glycerol" droplet intake due to droplet wicking testing*

Sample code	Droplet absorbed area (cm x cm)
N_control	3.34 ± 0.29 x 2.3 x 0.26
N_AV	2.50 ± 0.10 x 2.15 x 0.21
N_s1_AV	2.61 ± 0.23 x 2.09 x 0.28
N_s5_AV	2.84 ± 0.21 x 2.06 x 0.32
N_s10_AV	3.02 ± 0.21 x 2.05 x 0.16

Bending length of Cantilever bending testing gives an idea about the pliability of textile materials. Even though masks need to ensure a stable breathing area, certain amount of flexibility is required to have face fit for N95 respirator masks. Aloe Vera impregnated respirator substrates show shorter bending length compared to control samples. Shorter bending lengths indicate better pliability. Polypropylene is a strong polymer with low elongation properties which leads polypropylene to be a bad option to ply or bend it due to its intrinsic low elongation values. Impregnating polypropylene respirator substrates into Aloe Vera and sodium chloride solutions increased the pliability of respirator substrates. Increase of pliability for N95 respirator substrates might give freedom to give shape to the mask and increase face fitness of the respirator. Table 4 show the Cantilever bending test results of the samples. Bending length test results proved Aloe Vera impregnated respirator substrates had shorter bending length, as a result better pliability, compared to control samples.

Table 4. *Results for bending length*

Sample code	**Bending length (cm) (C= L*/2)**
N_control	1.85 ± 0.09
N_AV	1.43 ± 0.08
N_s1_AV	1.26 ± 0.11
N_s5_AV	0.98 ± 0.06
N_s10_AV	0.86 ± 0.03

L* is the length on the Cantilever ruler

3. CONCLUSIONS

Aloe Vera and salt loadings shortened sinking time of hydrophobic PP samples into glycerol. Polypropylene substrates showed hydrophobicity even when salt and Aloe Vera were impregnated on them. Wicking tests are tested with glycerol droplets. The droplet absorbed area is slightly decreased with salt loading, which might be a chance to tune mask material hydrophobicity level according to usage areas and user needs. The bending length “C” is decreased with salt loading and Aloe Vera application, the stiffness of polypropylene spunbond nonwoven is decreased by salt and Aloe Vera loading giving opportunity to shape the mask and increase face fitness of the respirator.

Wicking tests are a sign of good moisture transport, when conducted with water. However, our samples had no water absorption as they are originally polypropylene, a polymer that is hydrophobic. In this study, wicking area was calculated by letting a droplet of glycerol from 10 mm height. The property of absorbing glycerol is a sign of hydrophobicity which is good for preventing human body fluids from sticking on the fibrous materials such as wound dressing or facemasks touching wounds that are on their healing process [13]. The hydrophobic characteristics of the N95 mask fabric might be a good candidate for patients that have to wear masks over some wounded body part. Sinking times in glycerol show that Aloe Vera and sodium chloride impregnated samples have ability to take into hydrophobic fluids such as oils and proteins. The droplet absorbed area is slightly decreased with salt and Aloe Vera loading, which might be a chance to tune mask material hydrophobicity level according to usage areas and user needs. The hydrophobic characteristics of the N95 mask fabric might be a good candidate for patients that have to wear masks over some wounded body part as hydrophobic wound dressings are good candidates to heal wounds with thick exudates which are coagulation of proteins in the wounds and have hydrophobic characteristics.

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